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Soviet Plans for a Manned Flight to Mars

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An Intelligence Assessment

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SW 85-10061
May 1985

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Soviet Plans for a Manned Flight to Mars [redacted]

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An Intelligence Assessment

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Soviet Plans for a Manned Flight to Mars [redacted] 25X1

Key Judgments

Information available as of 1 March 1985 was used in this report.

[redacted] Soviet statements indicate that the Soviets are planning a manned Mars mission from which they hope to derive world acclaim and prestige. Because all the technologies needed for such a flight have not yet been perfected, the Soviets have not committed themselves to a launch date. Our strongest, current indicators of Soviet plans for a manned mission to Mars are the long-duration stays in space by cosmonauts and the Soviet program to develop magnetoplasma dynamic thrusters for long-duration space propulsion. [redacted] 25X1 25X1

The Soviets' first attempt almost assuredly will be a flyby, one year in duration, and probably have a three-person crew. We believe they could attempt such a mission in the mid-to-late 1990s. The fact that such a mission depends on successful Soviet development of a new booster, propulsion systems, on-orbit assembly techniques, and other advanced systems argues against an earlier date. [redacted] 25X1

The manned Mars spacecraft and propulsion system will have to be assembled in low-Earth orbit. Such an undertaking will require the Soviets to use their heavy-lift launch vehicles, now in development; a manned space station to support the assembly in orbit; and probably a space tug, now under development, to move large components into position for assembly. [redacted] 25X1

[redacted] the Soviets are investigating using nuclear energy to propel the spacecraft from Earth orbit. As an alternative, they could use conventional engines with cryogenic propellants. Either option would minimize the number of support launches and components to assemble in space. Storable-liquid engines such as they use in their current launch vehicles and liquid-fueled ICBMs would require considerably more fuel and, hence, support launches. Both the nuclear propulsion (which would require liquid hydrogen for the thrusters) and the cryogenic propellant conventional engine options will require the development of advanced refrigeration techniques and insulation capabilities to maintain the cryogenic materials in the liquid state. Although we are uncertain of the current status of Soviet efforts in these areas, the Soviets possibly could have both available by the mid-1990s. [redacted] 25X1 25X1

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Background

In the past several years, Soviet academicians, cosmonauts, political figures, and news media have indicated that a manned spaceflight to Mars is being considered and could be accomplished in the mid-to-late 1990s. Public comments in 1982 by the Soviet S&T attache assigned to Washington and in 1984 by the president of the Soviet Academy of Sciences suggest that the Soviets have confidence in their ability to conduct such a mission and probably believe that the United States is not in a position to compete with them in this endeavor for the world acclaim and the prestige they would expect to attain. Their interest in conducting such a mission may stem from the fact that they lost the race to the moon and may have been stimulated by past US interest in a manned Mars mission (see chronology of related US initiatives). [redacted] 25X1

The importance the Soviets are placing on long-term manned spaceflights, such as the recent 238-day record stay in space on Salyut 7, is a clear indication of interest in a planetary mission, because such long stays are not required for space stations or lunar flights. [redacted] 25X1

Mars Mission Essentials

A manned mission to Mars is a complex undertaking. Mission duration for even just a Mars flyby would be one year, putting a stress on component reliability and crew temperament. Because of the long duration, the spacecraft complex would have to be large, requiring multiple launches from Earth and on-orbit assembly. [redacted]

Orbital mechanics place inviolable constraints on a Mars mission. The motions of Mars and Earth about the sun dictate launch windows and trajectories (see figure 1). The choice of a particular launch time and trajectory is determined by a trade-off between mission duration and the amount of propellants needed. For example, the trajectory that would require the least amount of propulsion to reach Mars, the so-called minimum energy trajectory, would result in a 30-month voyage (including a 12-month time in orbit around Mars waiting for a return opportunity). Launch opportunities for such a minimum energy flight would occur about once every 26 months. [redacted] 25X1

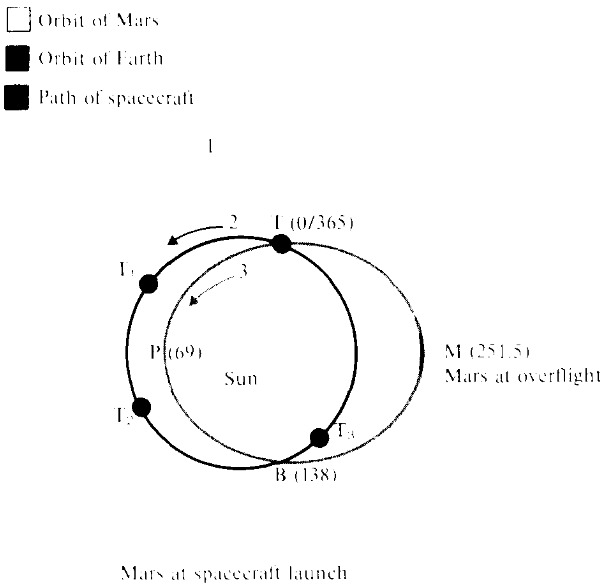
Chronology of Important US Initiatives Supporting a Manned Mars Mission

1952	*Werner von Braun published plan for manned exploration of Mars.*
1963	*American Astronautical Society held what is believed to be first conference on manned Mars missions; NASA-sponsored conference on manned Mars mission held.*
1965	*NASA, Virginia Polytechnic Institute, and the Air Force's Cambridge Research Laboratories sponsored conference on manned Mars mission; Senate hearings held on same topic.*
1967	*President's Science Advisory Committee recommended study of effectiveness of manned and unmanned planetary flybys and orbiters.*
1969	*Vice President Agnew proposed goal of manned Mars flight by end of century; US conducts successful manned lunar landing.*
1978	*Senate bill proposed to develop capability by 2010 to establish permanent settlement on Mars.*

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Figure 1
Diagram of One-Year Flyby Orbit



At the points 0, 69, 251.5, and 365 days, the Earth occupies in turn the positions T, T-1, T-2, T-3, and T, while the spacecraft finds itself successively at T (launching into the solar system), P (after having traversed the orbit of Venus, not shown in this diagram, and eventually overflown the planet), B (where it regains Earth orbit but not the Earth itself), M (overflight of Mars), and T (return to the Earth).

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We believe a more reasonable choice for the Soviets would be a one-year flyby mission as their first step. Such a mission would not require much more propellant than a minimum energy flight. The reduced mission duration, however, would decrease the impact of weightlessness on cosmonauts' health and would require substantially less ground support and life support supplies. Launch windows for a one-year flyby occur about once a year. We have chosen this option as the basis for assessing mission requirements in this paper. [redacted]

Mission Requirements
The Soviets will need their heavy-lift launch vehicle (HLLV)—now in development—for placing the Mars components into low-Earth orbit. The HLLV will be capable of placing into low-Earth orbit about five times the payload of the present largest Soviet space launch vehicle, thereby significantly reducing the number of launch vehicles required. They probably will need a space tug to move the large components into position for the required assembly in low-Earth orbit and a manned space station to support these construction activities. [redacted] 25X1

[redacted] the Soviets began developing the HLLV in the mid-1970s. This vehicle—a central core with four strap-on boosters—will be capable of delivering payloads of up to 100,000 kilograms (kg) to low-Earth orbit. Future variants of the vehicle using six strap-on boosters could place up to 150,000 kg in orbit. Launch and support facilities for the HLLV at Tyuratam are almost complete, and we believe they could support flight-testing as early as late 1985. [redacted] 25X1

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High-level Soviet officials have stated that they are developing a space tug. Both the Progress-series spacecraft and a multipurpose spacecraft (Cosmos 1443) have been used for orbital correction and stabilization of the Salyut space station complex. According to the Soviet media, Cosmos 1443 was designed as a "multipurpose vehicle," and variants of it can function as a freighter, an element of an orbital module, or as a space tug. [redacted] 25X1

Space station support could be provided by current or future Salyut space stations. The Soviets have discussed openly their plans to have a modular space station complex in the mid-to-late 1980s that will be formed by docking multiple Salyut-class spacecraft to a core vehicle. Their HLLV, if successfully developed, will be able to place large, Skylab-sized space stations into orbit by the late 1980s. Multiple, large space stations probably will be docked to form space bases in the 1990s. [redacted] 25X1

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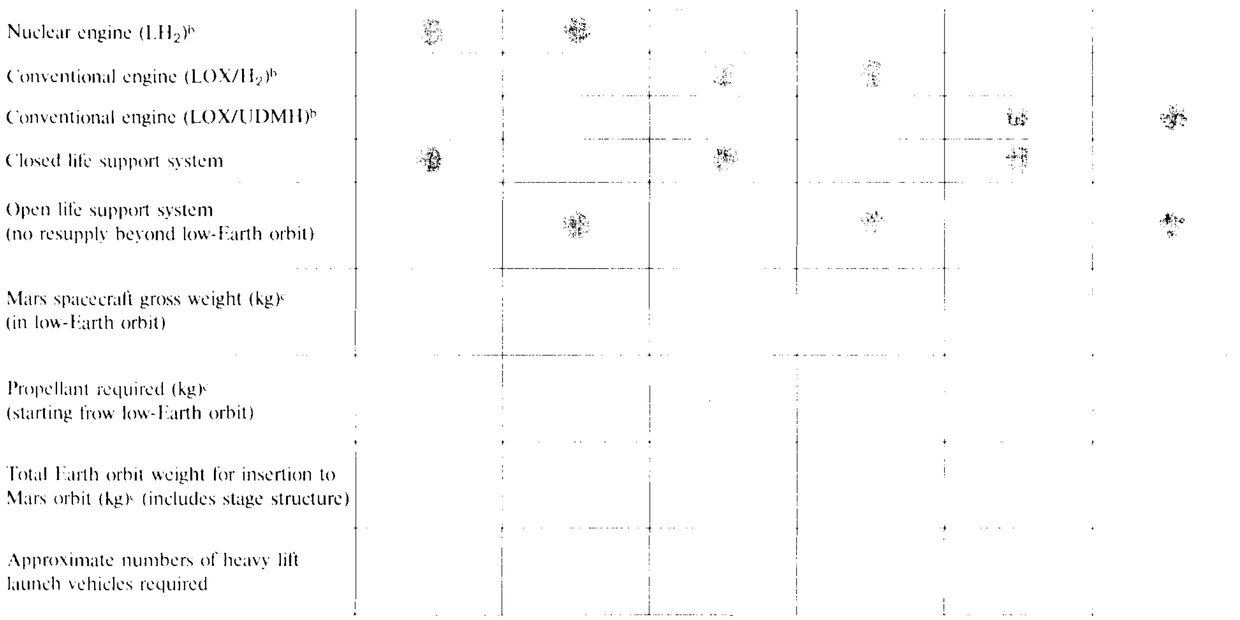
Spacecraft Options
Figure 2 shows the various propulsion and life support system options that are available to the Soviets for a one-year mission. It gives estimated weights of the spacecraft and propellant and total gross weight, as well as the number of support launches required for each option. [redacted] 25X1

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Figure 2
Estimated Requirements/Options for a Manned, One-Year Mars Mission[a]



[a] All options require assembly in low-Earth orbit.

[b] Engines and propellants required for a launch from low-Earth orbit:

Nuclear engine (H_2)	W/R ~2.45
Conventional (LOX/H_2)	W/R ~6.30
Conventional (LOX/UDMH)	W/R = ~25.00

(W/R weight ratio of spacecraft plus propellant to spacecraft typical of propellants and engine combinations considered).

[c] All weights are approximate.

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Soviet choice of engine and propellant combinations for their Mars spacecraft has the greatest impact on the number of HLLVs required to place components of the spacecraft into low-Earth orbit for assembly. Using currently available conventional engines with liquid oxygen and unsymmetrical dimethylhydrazine (LOX/UDMH) as propellants would require 14 or 15 HLLVs to orbit spacecraft components. Most of these components would be tanks of propellants. Assuming that more than one launchpad will be available and a 30-day turnaround time for each of these launchpads, at least several months would be required to orbit all components. [redacted]

We see two other Soviet choices for the Mars spacecraft propulsion system—a nuclear propulsion system or conventional engines with liquid oxygen and liquid hydrogen (LOX/LH_2) as propellants. Either would reduce the number of HLLVs needed over that needed with LOX/UDMH to orbit components, and fewer components would simplify assembly in orbit. 25X1 The Soviets will use LOX/LH engines on their HLLV, so such engines will be available. [redacted]

We know [redacted] the Soviets 25X1 were developing magnetoplasma dynamic (MPD) thrusters for use on a manned Mars mission, among other things. By 1978 the Soviets had begun development of 100- to 800-kilowatt MPD thrusters with an operating lifetime of 1,000 to 10,000 hours. Given the upper bound of lifetime hours and kilowatts, we 25X1 believe that the Soviets almost certainly have considered nuclear generation of electricity to power the

thrusters. In addition to propulsion, the nuclear source could be used to satisfy the 2-kilowatt-per-person-per-day power requirement that a Soviet claimed in 1981 would be needed to support a closed ecological system on a manned Mars spacecraft [redacted] 25X1

A major prerequisite in using cryogenic propellants for either nuclear or conventional engines would be the development of advanced on-orbit refrigeration techniques and a greatly improved insulation capability. Although we are uncertain of the current status of Soviet efforts in the areas of nuclear propulsion and on-orbit cryogenic propellant storage capability, the Soviets possibly could have both available by the mid-1990s. [redacted] 25X1

The Soviets could opt to use either an open- or a closed-cycle life support system. Choice of either one would have little impact on the required number of HLLVs. They have an open-cycle system and have been working on closed-cycle systems for over 15 years. In a Soviet test completed in early 1984, two people were totally self-sufficient for five months with the exception of electricity and television broadcasts. An article describing this experiment as a "complete success" stated that the closed biological system will be used in space "in the not too distant future." [redacted] 25X1

Mars Launch Windows Through 2001

Minimum energy opportunity	*May 1986*
	July 1988
	September 1990
	November 1992
	January 1995
	March 1997
	May 1999
	July 2001
One-year flyby opportunity	*November 1986*
	August 1987
	January 1989
	October 1989
	March 1991
	December 1991
	May 1993
	February 1994
	July 1995
	April 1996
	September 1997
	June 1998
	November 1999
	August 2000

[redacted] 25X1

[redacted] Indicators of Soviet Intentions and Progress

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Our strongest current indicators of Soviet plans for a manned mission to Mars are the long-duration stays in space by cosmonauts and the Soviet program to develop MPD thrusters. Other current indicators are ambiguous: the HLLV will be used to orbit their shuttle and other heavy payloads; a space tug can be used for assembly of other large structures in Earth orbit; and closed-cycle life support systems are desirable for space stations. [redacted]

Expected future indicators include: a cosmonaut stay in low-Earth orbit for one year, probably without being resupplied with consumables; space tests of MPD thrusters; advanced refrigeration and insulation; probably a space tug tested in low-Earth orbit; availability of HLLV launchpads; successful flight tests of the HLLV; assembly of a Mars spacecraft prototype in low-Earth orbit; and a flight to Mars of an unmanned prototype. [redacted]

Likelihood and Timing

On the basis of Soviet statements and activities, we believe the Soviets have a long-term goal of a manned flight to Mars. The question is when. [redacted] 25X1

We believe the use of conventional spacecraft engines with LOX/UDMH is unlikely because of the large number of HLLVs required and the complexity of joining so many components in space, which would likely reduce reliability below that required for a manned spacecraft. Moreover, the expense involved probably would be prohibitive. Rather, we believe that the Soviets will opt for nuclear propulsion or conventional spacecraft engines with LOX/LH_2. On the basis of past Soviet research, development, testing, and evaluation practices, we judge space tests and

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evaluation of new engines, advanced refrigeration, and advanced insulation will require several years. If these tests begin in 1985, we would not expect them to be completed before 1989 or 1990. 25X1

It is conceivable that the Soviets could attempt a manned Mars mission in the early 1990s; [1] however, we believe the mid-to-late 1990s is much more likely. The fact that such a mission depends on successful Soviet development of a new booster, propulsion systems, on-orbit assembly techniques, and other advanced technology systems argues against an earlier date. 25X1

[1] 1992 has a certain attraction. It will be the 75th anniversary of the Bolshevik Revolution, and the Soviets could be planning to launch a manned Mars mission as part of their celebration. Also, the West will be celebrating the 500th anniversary of Columbus's discovery of America, and it could be the year the US space station reaches operational status—two events from which the Soviets may want to detract attention. 25X1